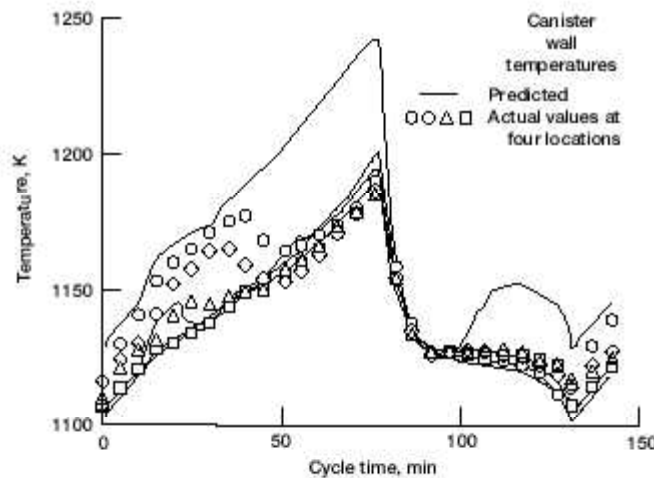


# **Radiation Heat Transfer Modeling Improved for Phase-Change, Thermal Energy Storage Systems**

Spacecraft solar dynamic power systems typically use high-temperature phase-change materials to efficiently store thermal energy for heat engine operation in orbital eclipse periods. Lithium fluoride salts are particularly well suited for this application because of their high heat of fusion, long-term stability, and appropriate melting point. Considerable attention has been focused on the development of thermal energy storage (TES) canisters that employ either pure lithium fluoride (LiF), with a melting point of 1121 K, or eutectic composition lithium-fluoride/calcium-difluoride (LiF-20CaF<sub>2</sub>), with a 1040 K melting point, as the phase-change material. Primary goals of TES canister development include maximizing the phase-change material melt fraction, minimizing the canister mass per unit of energy storage, and maximizing the phase-change material thermal charge/discharge rates within the limits posed by the container structure.

One key element for achieving these canister development goals is an accurate computational model of canister phase change heat transfer. An important, but heretofore understudied, aspect of the canister phase change problem is thermal radiation heat transfer. Radiation is the primary mode of heat transfer through salt-vapor-filled voids within the canister. These voids grow and shrink as the salt undergoes a 20- to 30-percent volume change during melting and freezing. In addition, the liquid salts are nearly transparent to radiation with wavelengths less than 5.5  $\mu$ m which encompasses fully three quarters of the spectral emissive power of a black body at LiF's melting temperature.

Cleveland State University (ref. 1) and the NASA Lewis Research Center developed such a canister heat transfer computational model. Building on Lewis' existing computational tools, Cleveland State developed an integrated model describing the canister's two- or three-dimensional conduction heat transfer with phase change, void behavior, and radiation heat transfer with participating media. Various combinations of radiation heat transfer modeling within the void and liquid salt were investigated. Computational results were compared with canister data obtained from both ground experiments (ref. 2) and space shuttle flight experiments (ref. 3). The graph shows one such comparison of predicted canister wall temperatures versus measured wall temperatures for the TES-1 flight experiment (ref. 4). Although the predicted temperatures of the four radiation model cases indicate substantial differences in canister heat transfer rates, all the cases reproduce important features in the experimental temperature set during the phase-change material solid sensible energy phase, liquid sensible energy phase, and thermal arrest periods. Computational results such as these could be used to optimize TES canister designs for minimum mass or maximum heat transfer rate and, thus, improve solar dynamic power system heat receiver designs. This kind of radiation heat transfer analysis tool could also find use in assessing other engineering problems such as combustion processes, furnace design, and radiant heater design.



*Canister wall temperature predictions for four cases of radiation modeling versus TES-1 flight experiment measured wall temperatures at four stations around the perimeter of the cylindrical canister.*

## References

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